A Centrifugal Pump for Graft Replacement of the Descending Thoracic or Thoraco-Abdominal Aorta

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A Centrifugal Pump for Graft Replacement of the Descending Thoracic or Thoraco-Abdominal Aorta

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Summary

Between January 1987, and December 1988, 14 cases of descending thoracic or thoraco-abdominal aortic aneurysm underwent operation using a prosthetic graft replacement. In order to avoid hypoperfusion to distal organs and proximal hypertension during aortic cross-clamping, two different adjuncts were used and the effectiveness of those methods were compared according to the results of surgery.

Seven patients were treated with a temporary shunt of heparin-bonded tube from the left axillary artery to left femoral artery, or else Dacron vascular prosthesis from right axillary artery to right femoral artery (Group I). In GroupII (seven patients), left heart bypass was performed, using a centrifugal pump from the left atrium to the left femoral artery with minimal heparinization.

In Group I, there were two hospital deaths, due to respiratory and hepatic failure respectively, and paraplegia has occurred in one case. In Group II, there was no death during a post-operative observation period of 5–15 months, and there was no case of paraplegia.

We think that temporary left heart bypass with a centrifugal pump seems to be the most useful method today for graft replacement of the descending thoracic or thoraco-abdominal aorta.

Introduction

Surgical management of descending thoracic or thoracoabdominal aortic aneurysms necessarily require temporary cross-clamping of this major arterial pathway. Such interruption without chronic obstruction causes severe sudden increases in peripheral resistance and left ventricular afterload. These abnormalities frequently lead to subendocardial ischemia sufficient to induce ventricular fibrillation or heart failure and cardiac arrest; death could result from either. Moreover, simultaneous proximal and distal descending thoracic aortic cross-clamping may cause temporary or

Key words: Descending thoracic aortic aneurysm, Thoraco-abdominal aortic aneurysm, Temporary left heart bypass, A centrifugal pump.
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permanent ischemic change to distal organs, particularly the spinal cord and kidneys, when the clamping time is extensive and collateral circulation is cut off.

In order to avoid these complications, various protective methods have been utilized. This clinical review was undertaken to compare the results of operation for the descending thoracic and thoraco-abdominal aortic aneurysm employing left heart bypass with a centrifugal pump and temporary shunt from proximal to distal aorta.

Clinical materials

From 1987 through 1988, excisional therapy was employed in 14 patients with descending thoracic or thoraco-abdominal aortic aneurysm. These can be divided into two groups.

In group I patients (7 cases) were operated on with the aid of a temporary shunt using a heparin-bonded tube or a vascular prosthesis. Group II consisted of 7 patients and a centrifugal vortex pump with minimal heparinization was used to obtain adequate perfusion of the distal aorta. The published clinical data are showed in Table 1.

Techniques

In group I, the shunts were performed with triomethylamonium-heparin bonded tubes from the left axillary artery to the left common femoral artery, or else with Dacron vascular prosthesis from right axillary artery to the right common femoral artery. When the Dacron vascular prosthesis was used for a temporary shunt, the position was supine initially. Two skin incisions were made in the right subclavicular region and in the right groin to expose right axillary and common femoral arteries.

After completion of the temporary shunt with the vascular prosthesis, the patient was turned to a right decubitus position.

When a heparin bonded tube was used, the patient was placed in the right decubitus position with the pelvis fixed at 45° throughout the operation, and posterolateral thoracotomy, with or without spiral abdominal incision consecutive to the former incision was performed. The aneurysm was resected after proximal and distal clamping, and replaced with an appropriately sized Dacron tube prosthesis. Pressures were monitored during the operative procedure by brachial and femoral arterial monitoring catheters.

In group II patients, the patient was placed in the same position as those who were treated with the heparin bonded tube in Group I patients, and the aorta was approached in a similar manner.

The pericardium was opened longitudinally, anterior to the phrenic nerve, the left atrial appendage incised and cannulated through a purse string suture, and the left common femoral artery was exposed and also cannulated in the usual fashion. After the bypass circuit was filled with lactate Ringer's solution, the centrifugal pump was started, then the flow was increased to 1.5–2.0 l/min and the aorta was cross-clamped proximally and distally to the aneurysmal lesion. The bypass flow rate was adjusted to equalize mean blood pressures measured in the radial and femoral arteries as much as possible. Graft replacement, with or without reanastomosis of the arteries in the abdominal viscera, was performed as previously mentioned in Group I patients.

After aortic crossclamps were removed, the bypass was discontinued, and the atrial and femoral cannule were removed as quickly as possible in order to avoid thrombosis.

Results

Table I and II summarize the background data, aortic cross-clamp time, outcome, and associated disorders for both patients who received shunt (Group I) and for those who had partial left heart bypass using a centrifugal pump (Group II).

In Group I, case 5 died on the eighteenth post-operative day due to hepatic failure and on the fifth post-operative day case 7 succumbed to respiratory failure. Paraplegia developed in case 1, and prolonged jaundice probably due to hepatic hypoperfusion during aortic cross-clamp was seen in case 3 until the tenth post-operative day but with ultimately successful recovery from it. Another 3 patients ultimately recovered despite significantly prolonged ventilatory care on a respirator in the intensive care unit.

In Group II, there was no death during a post-operative observation period of 5–15 months inspite of the fact that this group included cases who were treated with a more invasive procedure because of the larger extent of aortic involvement. Case 11 showed a decrease in temperature due to an extended thoraco-abdominal incision and prolonged perfusion, developed ventricular fibrillation and had narrow escape following several resuscitative measures through rethoracotomy. Localized thrombo-embolism in the occipital region apparently caused by the release of atheromatous plaque in the aortic arch with aortic cross-clamping between the left common carotid artery and the left subclavian artery occured in case 12. He recovered following six months of rehabilitation with minimal cerebral function dificit. In case 13, transient liver dysfunction of unknown cause was recognized for several days, but soon after he recovered completely. The other 4 cases showed such satisfactorily uneventful coureses that the endotracheal tube could be extubated on the second post-operative day. No cases of paraplegia or renal failure were encountered in this group.

Discussion

The temporary cross-clamping of the major arterial pathway necessary for graft replacement on the descending or the thoraco-abdominal aorta results in severe sudden increases of the left ventricular afterload by proximal hypertension.

Moreover, the peripheral hypoperfusion caused by such aortic interruption may cause temporary or permanent ischemic injury to distal organs, such as paraplegia and renal insufficiency, which constitute the most serious complications of this operation and occasionally lead to death. As well as the above problems, bleeding during and after surgery is also a major risk in cases of fragile aortic walls or high dose heparinization.

In order to avoid these devastating and occasionally fatal complications, various methods have been developed, although complete agreement concerning them has not yet been obtained [4,5,8,12–14,17–20].

In the early attempts of this type of surgery, left atrium—femoral artery bypass or femoral vein—femoral artery bypass with an oxygenator was commonly used[1,9,15] requiring heparinization with attendant disadvantages. Paraplegia occured in 5 out of a consecutive series of 72 cases[1,9,15].

The extraluminal shunts with vascular prosthesis[11] which were sewn on to the aorta or subclavian artery proximally and distally to the femoral artery, are intricate to place, occupy much space in the operating field, and the surgeon had no way of assessing or controlling the blood flow through them.

Table I

Background data

Group I : Shunt with heparin bonded tube or prosthetic graft

Patient #	Age	Sex	Lesion	Etiology	Adjunct
1	53	F	Descending thoracic aneurysm	Atherosclerotic	Heparin bonded tube
2	70	M	Descending thoracic aneurysm	Atherosclerotic	Heparin bonded tube
3	63	M	Descending thoracic aneurysm	Atherosclerotic	Heparin bonded tube
4	62	M	Descending thoracic aneurysm	Atherosclerotic	Prosthetic graft
5	59	M	Descending thoracic aneurysm	Luetic	Prosthetic graft
6	63	F	Thoraco-abdominal aneurysm	Atherosclerotic	Prosthetic graft
7	78	M	Descending thoracic aneurysm	Atherosclerotic	Prosthetic graft

Group II : Temporary left heart bypass with centrifugal pump

8	52	M	De Bakey IIIb dissecting aneurysm	Arteriosclerotic	Centrifugal pump
9	72	M	Descending thoratic aneurysm	Traumatic	Centrifugal pump
10	61	M	Thoraco-abdominal aneurysm	Atherosclerotic	Centrifugal pump
11	59	M	Abdominal dissecting aneurysm	Arteriosclerotic	Centrifugal pump
12	60	M	Descending thoracic aneurysm	Atherosclerotic	Centrifugal pump
13	49	M	De Bakey IIIb dissecting aneurysm	Arteriosclerotic	Centrifugal pump
14	39	F	Descending thoracic aneurysm	Inflammatory due to S.L.E.*	Centrifugal pump

*S.L.E. : Systemic lupus erythematodes

Table II

Results

Group I

Patient #	Ao-X time(min)	ACT+(sec)	Morbidity	Outcome
1	115	↑	paraplegia	alive
2	77	|	none	well
3	82	non	none	well
4	95	heparinization	jaundice	well
5	125	|	hepatic failure	died
6	90	|	none	well
7	88	↓	respiratory failure	died

Group II

8	89	165～275	none	well
9	81	127～147	none	well
10	75	114～180	none	well
11	155	127～376	descent of bodytemp., VF	alive, well
12	127	157～250	brain embolism	alive
13	135	204～265	transient liver dysfunction	alive, well
14	77	150～230	none	well

+A.C.T. : Activated coagulation time

Because heparin-bound indwelling shunts have the benefit of not requiring heparinization, many surgeons adopted this method but could not reduce the incidence of paraplegia and mortality due to the occasional insufficiency of distal flow, despite the marked simplification of technical procedures[4,10,13,14,20].

CRAWFORD[6] reported a most impressive consecutive series of 112 cases, in which simple cross-clamping of the aorta in conjunction with pharmacological control of cardiac and circulatory hemodynamics was employed. In his latest series, paraplegia did not occur and the survival rate increased to 94% with adequate monitoring and control of the hemodynamics of proximal circulation. His skill and rapidity appear to be related to his achieving such excellent results without any adjunctive methods or heparin. The authors feel that those who operate more slowly have to depend on some adjunctive methods.

CONNOLLY and WAKABAYASHI [3,18,19] modified the left heart bypass technique by employing non-thrombogenic coated tubing from the left atrium to femoral artery with an interposed roller-pump. The relative absence of intraoperative and postoperative bleeding was the most dramatic and significant feature noted in ten patients who successfully underwent resection of descending thoracic aortic aneurysm. However prolonged perfusion by a roller-pump may cause hemolysis by mechanical injury to blood cells.

The method of left heart bypass which consists of left atrial drainage line, centrifugal pump and arterial infusion line is quite simple and can provide excellent flow into the distal organs, thereby allowing afterload reduction and decreased left ventricular strain, with or without minimal heparinization[2].

OLIVIER et al[16] reported a successful series of surgery in cases with intimal tears of thoracic aorta, using this technique, while another series led to death or paraplegia in six of ten patients with shunt or simple aortic cross-clamping.

CRAWFORD[7], however, described 118 operative survivors of the descending thoracic or thoracoabdominal aoric aneurysm treated with this method of left heart bypass, and the incidence of spinal cord dysfunction was 17%. Of interest is the fact that the larger flow associated with lower pressure were associated with less neurologic injury than high pressure associated with lower flow.

Thus, to date, there is no convincing clinical evidence that one method of operation is superior reducing of complications, the additional new strategies are required[7,14].

Temporary left heart bypass with a centrifugal pump from left atrium to the left femoral artery for the graft replacement of the descending thoracic or thoraco-abdominal aorta has several benefits as follows:

1. It can provide sufficient blood flow to distal organs and control of blood flow during aortic cross-clamping.
2. It can prevent proximal hypertension, reducing left ventricular strain therefore the post-oprative complications due to cardio-pulmonary disorders should be able to be prevented.
3. There is no necessity to change the operative position, thereby facilitating the surgical procedure.
4. It is feasible to undergo left heart bypass with minimal heparinization, which reduces bleeding during and after operation.

Conclusion

The temporary left heart bypass with centrifugal pump is a feasibe adjunctive method which can

be employed for the graft replacement of the descending thoracic and thoraco-abdominal aorta.

References

1) Bloodwell RD, Hallman GL, Cooley DA. Partial cadiopulmonary bypass for pericardiectomy and resection of descending thoracic aortic aneurysms. Ann Thorac Surg 6: 46–56, 1968.
2) Colon R, Frazier OH, Cooley DA, McAllister HA. Hypothermic regional perfusion for protection of the spinal cord during periods of ischemia. Ann Thorac Surg **43**: 639–43, 1987.
3) Connolly JE. Prevention of paraplegia secondary to operations on the aorta. J Cardiovasc Surg **27**: 410–7, 1986.
4) Connors JP, Ferguson TB, Roper CL, Weldon CS. The use of the TDMAC-heparin shunt in replacement of the descending thoracic aorta. Ann Surg **181**: 735–41, 1975.
5) Crawford ES, Rubio PA. Reappraisal of adjunts to avoid ischemia in the treatment of aneurysms of descending thoracic aorta. J Thorac Cardiovasc Surg **66**: 693–704, 1973.
6) Carwford ES, Walker HSJ, Saleh SH, Normann NA. Graft replacement of aneurysm in descending thoracic aorta: Results without bypass or shunting. Sugery **89**: 73–85, 1981.
7) Crawford ES, Mizrahi EM, Hess KR, Coselli JS, Safi HJ, Patel VM. The impact of distal aortic perfusion and somatosensory evoked potential monitoring on prevention of paraplegia after aortic aneurysm operation. J Thorac Cardiovasc Surg **95**: 357–67, 1988.
8) DeBakey ME, McCollum CH, Graham JM. Surgical treatment of aneusysms of the descending thoracic aorta. J Cardiovasc Surg **19**: 571–6, 1978.
9) DeBakey ME, Cooley DA, Crawford ES, Morris GC Jr. Aneurysms of the thoracic aorta: Analysis of 179 patients treated by resection. J Thorac Surg **36**: 393–420, 1958.
10) Donahoo JS, Brawley RK, Gott VL. The heparin-coated vascular shunt for thoracic aortic and great vessel procedures: a ten-year experience. Ann Thorac Surg **23**: 507–13, 1977.
11) Koie H. Sugery of thoracic aortic aneurysm. J Jap Assoc Thorac Surg **27**: 1018–25, (in Japanese) 1979.
12) Kouchoukos NT, Lell WA, Karp RB, Samuelson PN. Hemodynamic effects of aortic clamping and decompression with a temporary shunt for resection of the descending thoracic aorta. Surgery **85**: 25–30, 1979.
13) Lawrence GH, Hessel ES, Sauvage LR, Krause AH. Results of the use of the TDMAC-heparin shunt in the surgery of aneurysms of the desecending thoracic aorta. J Thorac Cardiovasc Surg **73**: 393–8, 1977.
14) Najafi H, Javid H, Hunter J, Serry C, Monson D. Descending aortic aneurysmectomy without adjuncts to avoid ischemia. Ann Thorac Surg **30**: 326–35, 1980.
15) Neville WE, Cox WD, Leininger B, Pifarré R. Recection of the descending thoracic aorta with femoral vein to femoral artery oxygenation perfusion. J Thorac Cardiovasc Surg **56**: 39–42, 1968.
16) Olivier HF Jr, Maher TD, Liebler GA, Park SB, Burkholder JA, Magovern GJ. The use of the biomedicus centrifugal pump in traumatic tears of the thoracic aorta. Ann Thorac Surg **38**: 586–91, 1984.
17) Real GJ Jr, Cooley DA, Hallman GL, Reddy SB, Kyger ER. Dissecting aneurysms of the descending aorta: Improved surgical results in 91 patients. Arch Surg **110**: 632–40, 1975.
18) Wakabayashi A, Connolly JE, Stemmer EA, Nakamura Y, Kubo T, Ino T. Heparinless left heart bypass for resection of thoracic arotic aneurysms. Am J Surg **130**: 212–8, 1975.
19) Wakabayashi A, Connolly JE. Prevention of paraplegia associated with resection of extensive thoracic aneurysms. Arch Surg **111**: 1186–9, 1976.
20) Wolfe WG, Kleinman LH, Wechsler AS, Sabiston DC Jr. Heparin-coated shunts for lesions of the descending thoracic aorta. Arch Surg **112**: 1481–7, 1977.

和文抄録

胸部下行及び胸腹部大動脈人工血管置換術における遠心ポンプによる一時左心バイパスの有用性

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1987年1月より1988年12月の期間に14例の胸部下行又は胸腹部大動脈人工血管置換術を施行した．大動脈遮断中における末梢側臓器血流不全及び中枢側高血圧を避けるために，2種類の補助手段を使用し，それらの効果の差異を手術結果に基づいて比較検討した．

7例はヘパリンコーティングチューブで左腋窩動脈・左大腿動脈間に，又は径 12 mm のダクロン人工血管で右腋窩動脈・右大腿動脈間にそれぞれ一時シャントを設置した（Ⅰ群）．第Ⅱ群の7例では最小量の全身ヘパリン化のもとに，左心房・左大腿動脈間に遠心ポンプを用いた一時的左心バイパスを補助手段として使用した．

Ⅰ群では，2例が術後呼吸不全及び肝不全を来しそれぞれ死亡し，1例に術後対麻痺が発生した．Ⅱ群では術後5～15ヵ月の観察で死亡はなく，対麻痺の発生もみられなかった．

胸部下行及び胸腹部大動脈人工血管置換術において，遠心ポンプを用いた一時左心バイパス法は現在の所，最も有用な補助手段と思われる．